Chapter 6
Channel Modifications

6-1. Overview

This chapter describes the impact of channel modifications (sometimes called channel improvements) and hydrologic engineering requirements for planning these modifications to reduce flood damage. A checklist of the requirements is presented as Table 6-1.

6-2. Applicability

Channel modifications are effective flood-damage reduction measures in the following cases:

a. Damageable property is locally concentrated.

b. A high degree of protection, with little residual damage, is desired.

c. A variety of property, including infrastructure, structures, contents, and agricultural property, is to be protected.

d. Sufficient real estate is available for location of the reservoir at reasonable economic, environmental, and social costs.

e. The economic value of damageable property protected will justify the cost of modifying the channel.

Table 6-1
Checklist for Channel Modification

Hydrologic Engineering Study Components	✓	Issues
Layout		Determine right-of-way restriction
		Delineate environmentally sensitive aquatic and riparian habitat
		Identify damage centers, delineate developed areas, define land uses for site selection
		Identify infrastructive/utility crossing conflicts
Economics		Determine with-project modifications to stage-discharge function for all conditions
		Determine any downstream effects due to frequency function changes due to loss of channel storage
		Quantify uncertainty in stage-discharge function
		Formulate and evaluate range of channel configurations using risk-based analysis procedures
Performance		Determine expected annual exceedance probability
		Determine expected lifetime exceedance probability
		Describe operation for range of events and analyze sensitivity of critical assumptions
		Describe consequences of capacity exceedances
		Determine event performance
		Formulate OMRR&R plan and prepare O&M manual to include surveillance and flood fighting
Design		Account for ice/debris, erosion/deposition/sediment transport, high velocities
		Evaluate straightening effects on stability
		Evaluate all impact of restrictions/obstructions
Environmental and Social		Evaluate aquatic and riparian habitat impact and identify enhancement opportunities
		Anticipate and identify incidental recreation opportunities

6-3. Channel Overview

Stage in the floodplain is a function of: the channel discharge rate; the channel geometry, including invert slope, cross-sectional area, wetted perimeter, length, and alignment; and the energy "lost" as water is conveyed in the channel. This chapter focuses on measures that reduce out-of-bank stage (and hence, damage) by modifying the geometry or by reducing the energy loss.

a. Channel geometry modification.

(1) The out-of-bank stage can be reduced for a given discharge rate if the channel is modified to increase the effective cross-sectional area. Figure 6-1 shows such a modification. In this elevation versus station plot, the original boundary is shown as a solid line. When the material represented by the shaded polygons is removed, the new boundary is established, as shown. Now the total cross-sectional area beneath the water surface shown is greater than the without-plan area.

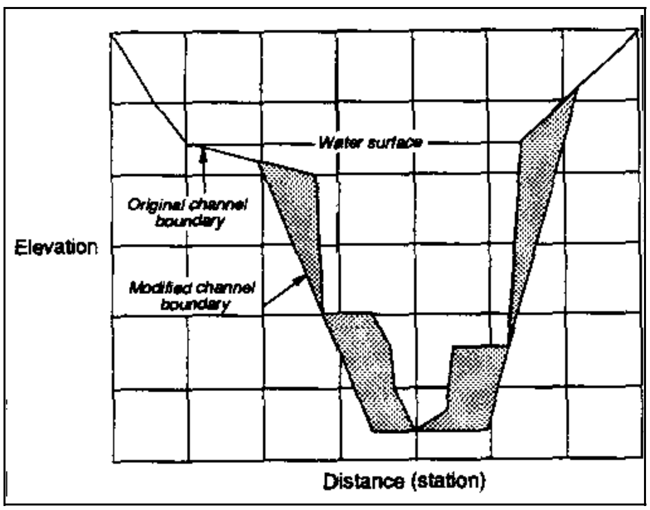

Figure 6-1. Illustration of channel geometry modification

(2) In the simplest case (steady, one-dimensional flow), discharge rate is directly proportional to cross-sectional area. Thus, if all else remains equal, the "improved" channel shown in Figure 6-1 will convey a greater discharge with water surface at the same elevation or the same discharge at a reduced water-surface elevation.

(3) The hydrologic engineering study should recognize that natural channel-geometry modifications may also take place, due to erosion and deposition or to bank instability. In either case, these will affect future with-plan and without-plan conditions. For example, if land-surface erosion increases as a consequence of development in a catchment, this sediment may be deposited in the channel. Without maintenance, this deposition will reduce the cross-sectional area over time, increasing stage for a specified discharge, and increasing EAD for the without-project condition ($E[D_{without}]$ in Equation 2-3). Similarly, scour may cause bank failure, thereby decreasing the effective flow area. This, too, may increase stage and the resulting EAD.

b. Energy loss reduction.

(1) As water is conveyed in a channel, energy is converted from one form to another or "lost." As this loss of energy results in increased stage, stage may be reduced by reducing the energy loss. This may be accomplished by smoothing the channel boundary, straightening the channel, or minimizing the impact of obstructions in the channel.

(2) The variation of water-surface elevation along a stream is largely a function of the boundary roughness and the stream energy required to overcome friction losses (EM 1110-2-1416). If all else remains the same, smoothing the channel to reduce the roughness will reduce the energy loss, which will in turn reduce stage and EAD.

(3) The total energy loss due to friction between two points on a stream is the product of the energy loss per unit length and the distance between the points. Clearly if the stream distance can be reduced, the energy loss and stage may be reduced. Figure 6-2 illustrates how this may be accomplished. The original channel alignment is shown with the gray boundary. The boundary of the realigned channel is dotted. In this case, the energy loss in the improved channel is less and the stage and damage will be reduced. EM 1110-2-1416 explains further that although water-surface profiles are mostly influenced by friction forces, changes in the energy grade line and the corresponding water-surface elevations can result also "... from significant changes in stream velocity between cross sections." These velocity changes may be the result of natural or man-made expansions or contractions in channel width or of bridge crossings in which discharge is forced through an opening smaller than the upstream and downstream channels. To avoid the increase in stage, transitions must be designed carefully, following guidance in EM 1110-2-1416. Similarly, if restricted bridge openings cause stage increases, removal or modification of the bridges should be considered as a feature of the flood-damage-reduction plan.

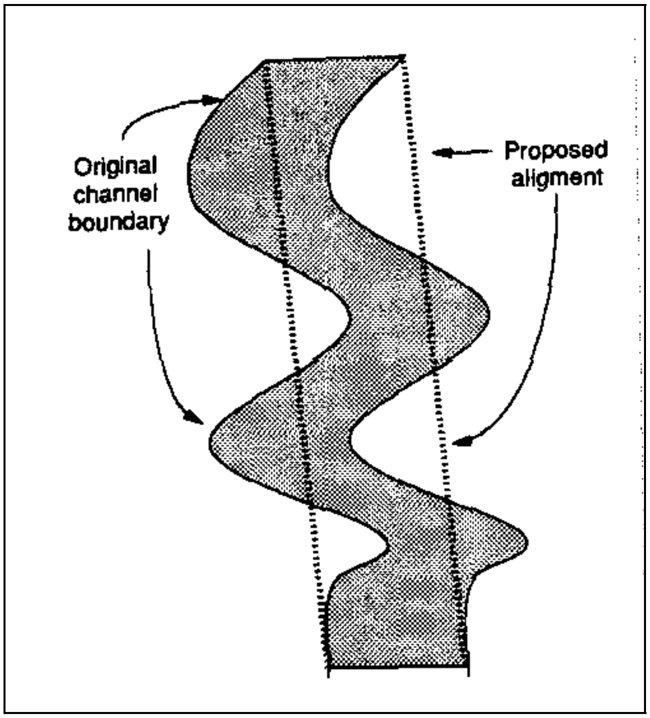

Figure 6-2. Channel re-alignment for damage reduction

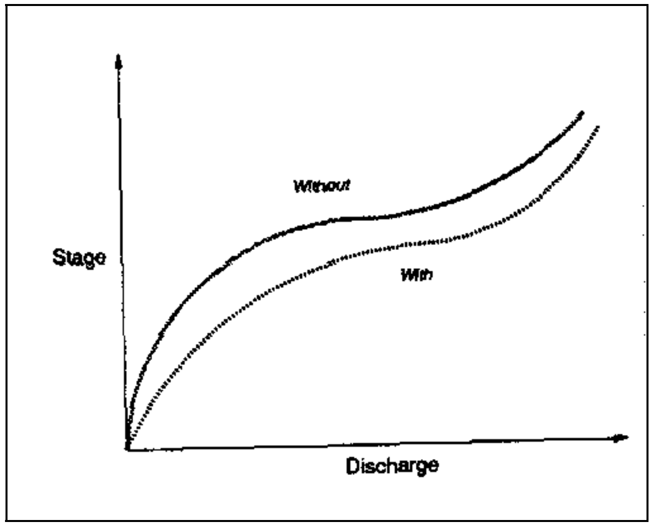

Figure 6-3. Stage-discharge function modifications due to channel improvement

6-4. Stage-Reduction Assessment

a. The intended impact of a channel modification is reduction of stage for a given discharge, as illustrated by Figure 6-3. In this figure, the existing, without-plan rating function is shown as a solid line, and the with-plan function is dotted. The modified rating function here shows a lower stage for all discharge values.

b. The impact of a channel modification can be evaluated with river hydraulics models as described in EM 1110-2-1416. These conceptual models have physically based parameters that can reflect the modifications. For example, the HEC-2 computer program, which is described in Appendix B of this manual, includes a model of GVSF. The program uses the physical dimensions of the channel and Manning's *n* (an index of channel roughness) directly to estimate stage. To evaluate the impact of a proposed channel widening, for example, the program input can be modified to reflect the changes. Repeated solution of the GVSF equations for selected discharge rates yields the stage-discharge function for a proposed channel configuration. Likewise, if the proposed plan includes channel smoothing, Manning's *n* value can be changed to reflect this, the program re-run, and the modified-condition rating function determined.

c. Several additional computer programs that embody river hydraulics models appropriate for analysis in other cases are described in Appendix B of this manual and in EM 1110-2-1416.

d. Channel modifications can also affect the discharge-frequency function. In many cases, the modifications will increase velocity in the improved section. Downstream, where no improvements have been made, this will yield greater discharge and, hence, an increase in frequency function quantiles. Further, the channel modifications may eliminate some of the natural storage in the channel. This natural storage, like the storage in a reservoir, would reduce flood peaks. In its absence, the downstream peaks may increase, and this too yields an increase in frequency function quantiles.

6-5. Incidental Impact of Channel Modifications

Channel modifications may also alter the discharge-frequency function if the modifications significantly reduce the timing of the hydrograph through the channel reach. For example, the channel re-alignment illustrated in Figure 6-2 reduces the timing between the upstream and downstream cross sections by reducing its length. This reduction, in turn, may result in an increase in the downstream discharge peak for an event of specified probability. Major channel modifications cause an increase in cross section, as illustrated in Figure 6-1, may increase the storage capacity, and, consequently, reduce the downstream peak for an event of specified probability.

The hydrologic engineer must be aware of the possibility of these incidental impacts, should investigate the change in timing and storage, and must define modified discharge-frequency functions if appropriate.

6-6. Technical Considerations

To ensure that channel modifications yield the damage reduction anticipated, the hydrologic engineer, when formulating and evaluating alternative plans, must give careful consideration to identification and solution of erosion and deposition problems, design for stability (especially if high velocities are anticipated), protection from ice and debris, and provision for on-going OMRR&R.

a. Erosion and deposition.

(1) EM 1110-2-4000 describes the myriad difficulties of sedimentation in rivers and reservoirs. When channel modifications are implemented, some of these problems may worsen. For example, if roughness is decreased, velocity increases, and the likelihood of erosion increases. If deposition was occurring in the without-plan condition, it may or may not continue. Similarly, if a channel is straightened, as shown in Figure 6-2, the stream slope increases, and the potential for deposition increases where the improved reach rejoins the natural alignment downstream, and the potential for scour increases at the transition from the natural reach upstream. Sedimentation studies are required to identify these and other related performance problems.

(2) Design guidance presented in EM 1110-2-1601 identifies the following solutions, which should be considered a part of the plan if necessary to ensure proper performance: (a) stabilizers constructed of grouted or ungrouted rock, sheet piling, or a concrete sill, placed normal to the channel center line, traversing the channel invert, and designed to limit channel degradation; (b) drop structures designed to reduce channel slopes, thus yielding nonscouring velocities; (c) debris basins and check dams to trap and store bed-load sediments.

(3) Channels that convey high velocity (supercritical) flow require special attention. High-velocity channel design must account for the effects of air entrainment, cross waves, superelevation at channel bends, and increased erosion potential. EM 1110-2-1601 provides additional guidance on design of channels.

b. Ice and debris.

(1) Channels in cold regions and channels that carry floating debris (logs and vegetation) can cause special flooding problems. The formation of ice jams and the collection of floating debris at flow constrictions, like bridge crossings, can cause flooding upstream, as the bridge behaves like a dam. The formation of ice jams and the collection of floating debris at flow constrictions also may cause excessive scour due to a local increase in velocity. With such a buildup, the flood discharge must pass through an area that is constricted both laterally and vertically. This leads to increased velocity, which in turn leads to erosion of bed material near the constriction. Likewise, the channel bank in this area might be undermined and ultimately fail.

(2) The hydrologic engineering study must recognize the potential for this, should evaluate system behavior when it does occur, and must design an OMRR&R plan to minimize the likelihood of ice and debris problems. EM 1110-2-1612 describes channel ice formation, ice jams, ice control, and methods for dispersion of floating ice. Similar measures may be required for debris dispersion.

c. OMRR&R. ER 1110-2-1405 requires that a local flood protection project (including channel improvements) include an OMRR&R plan to ensure that the modifications continue to function and provide protection as designed. This feature should provide for continuing inspection of the channel to identify evidence of scour damage to bank protection, significant erosion or deposition of sediment in the channel, and growth of vegetation that will increase resistance, thus increasing stage. The cost of this inspection and the anticipated cost of OMRR&R must be included as a component of the total plan cost.

6-7. Capacity-Exceedance Analysis

As with all proposed flood-damage-reduction plans, the impact of channel capacity exceedance must be evaluated. In the case of channel improvements, this may be accomplished with the appropriate river hydraulics model, using a steady flow or hydrograph with peak that exceeds the selected capacity. The hydrologic engineering study should ensure that topographic data that are assembled for formulation and evaluation include sufficient description of the floodplain outside the channel banks.

6-8. Environmental Impact

Channel modifications can have significant environmental impacts. For example, certain fish species depend on a pool-riffle aquatic environment typical of low flow in a meandering channel. If such a channel is straightened, the habitat will be disrupted, and the change may be lead to reduction in the fish population. The hydrologic engi neering analysis should identify such impacts. This will require consultation with environmental specialists. Similarly, consideration must be given to the environmental impact of increased turbidity during construction activities. Potential sources of fine-grained sediment should be identified, and a construction plan should be developed to control runoff from the construction site and to minimize the increase in sensitive areas of the stream.